1290036

TECHNICAL SPECIFICATIONS
ST. LOUIS TUNNEL DISCHARGE
WETLAND DEMONSTRATION

Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Dolores County, Colorado

Prepared for:
Atlantic Richfield
La Palma, California

Prepared by:
AMEC Environment & Infrastructure, Inc.
Rancho Cordova, California

December 2013

Project SA11161315

REVISION SUMMARY

Revision	Date Issued	Author(s)	Affected Technical Specifications	Approver(s)	Date Approved
---	12/31/13	B. Florentin (AMEC)	Issued for U.S. EPA review.	S. Archer (AMEC)	12/31/13

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

TECHNICAL SPECIFICATIONS
ST. LOUIS TUNNEL DISCHARGE
WETLAND DEMONSTRATION

Rico-Argentine Mine Site
Dolores County, Colorado

SECTION 1 – SUBMITTALS

1.0 GENERAL

This section specifies the general methods and requirements of submissions applicable to project related submittals.

1.1 REQUIREMENTS

1.1.1 Submittal Types

Submittals will include but are not limited to the following.

1. Construction schedule
2. Any required configuration drawings requested by the Engineer
3. Soil compaction reports
4. Dewatering plan
5. Shop drawings

1.1.2 Shop Drawings

1. Submit shop drawings as called out by the technical specifications in accordance with this section.
2. The use of Construction Drawing reproductions for shop drawings is unacceptable.
3. Submit four copies of shop drawings. The Engineer will keep two copies and return two copies. If the Contractor desires more than two copies, he shall transfer the Engineer's comments onto additional copies at his own effort. Clearly indicate the technical specification section, and Construction Drawing number to which each shop drawing is referenced.
4. Shop drawings will be returned to the Contractor after Engineer review with one of the following designations.
    a. Approved
    b. Approved with changes noted

c. Revise and resubmit

d. Rejected

1.1.3 Submittal Register

Designate in a submittal register/schedule, coordinated with the construction schedule, the date for submission and the date of reviewed shop drawings and product data. The submittal register shall include the submittal description, technical specification section and/or referenced Construction Drawing number, date to be submitted, date reviewed, and date acceptable submittal is required.

1.1.4 Submittal Requirements

1. Provide submittals promptly in accordance with the submittal register/schedule and in such sequence as to cause no delay in the work. Schedule submission a minimum of 14 calendar days before reviewed submittals will be needed or as approved by the Engineer.

2. Submittals shall contain the following.

    a. The date of submission and the dates of any previous submissions

    b. The project title and number

    c. The names of:

        i. Contractor

        ii. Supplier

        iii. Manufacturer

    d. Identification of the product, with the technical specification section number and Construction Drawing number

    e. Field dimensions, clearly identified as such

    f. Relationship to adjacent or critical features of the work or materials

    g. Identification of deviations from contract documents

    h. Identification of revisions on resubmittals

3. Contractor's stamp, initialed or signed, shall certify Contractor's review of submittal, verification of products, field measurements and field construction criteria, and coordination of the information within the submittal that the product meets the requirements of the work and of the contract documents.

1.1.5 Submittal Format

1. Each submittal shall have a transmittal form. A sample transmittal form is included at the end of this section. Every page in a submittal shall be numbered in sequence. Each copy of a submittal shall be collated and stapled or bound, as appropriate. Copies not collated will be rejected.

2. Where product data from a manufacturer is submitted, clearly mark which model is proposed, with all pertinent data, capacities, dimensions, clearances, diagrams, controls, connections, anchorage, and supports. Present a sufficient level of detail for assessment of compliance with the contract documents.

3. Each submittal shall be assigned a unique number. Submittals shall be numbered sequentially. The submittal numbers shall be clearly noted on the transmittal. Original submittals shall be assigned a numeric submittal number. Resubmittals shall bear an alphanumeric system which consists of the number assigned to the original submittal for that item, followed by a letter of the alphabet to represent that it is a subsequent submittal of the original. For example, if Submittal 25 requires a resubmittal, the first resubmittal will bear the designation “25-A”, the second resubmittal will bear the designation “25-B”, and so on.

1.1.6 Resubmittals

Resubmittal of submittals will be reviewed and returned in the same review period as for the original submittal. It is considered reasonable that the Contractor shall make a complete and acceptable submittal by the second submission of a submittal item. Resubmittals shall be prompt and comply with execution schedule requirements.

1.1.7 Contractor's Jobsite Drawings

Provide and maintain on the jobsite one complete set of prints of all drawings that form a part of the contract. Immediately after each portion of the work is installed, indicate all deviations from the original design shown in the Construction Drawings either by additional sketches or red ink thereon. Upon completion of the job, deliver this record set to the Engineer.

1.2 EXECUTION

Following is an example submittal form (see following page).

SHOP DRAWING SUBMITTAL NO. _____

AMEC

ATTN: _____ **ATTN:** _____

PROJECT NO.	PROJECT OWNER PROJECT NO.	CONTRACTOR PROJECT NO.

ITEM NO.	COPIES	DESCRIPTION	PREVIOUS SUBMITTAL NO.	SPEC. SECTION NO.	PLAN SHEET NO.

SUBMITTED BY: _____ _____

CONTRACTOR **DATE**

SUBMITTAL RETURN **(TO BE COMPLETED BY ENGINEER)**

ITEM NO.	COPIES	RESUBMIT		COMMENTS
		YES	NO	

COPY: **RETURNED BY:** _____ _____

ENGINEER **DATE**

SECTION 2 – QUALITY ASSURANCE / QUALITY CONTROL

2.0 GENERAL

This section specifies quality assurance and quality control (QA/QC) requirements.

2.1 EXECUTION

Specific QA/QC requirements are identified elsewhere in these technical specifications. Contractor shall submit QA/QC paperwork to the Engineer in accordance with Sections 3, 4, 5, 6, and 7. A sample of QA/QC requirements appears in the table below. These are provided for convenience only; the contractor is responsible for all submittals identified in the technical specifications.

QA/QC Requirements

Reference Spec	Material	Condition	Required Test	Frequency	Due Date
3.2.1	Fill	New Source	Material confirmation	One time	Delivery date
3.2.1	Fill	In-place	Compaction	Once a day	End of day
3.2.2	Structural Fill	New Source	Gradation	One time	Delivery date
3.2.2	Structural Fill	In-place	Compaction	Once a day	End of day
3.2.3	Pipe Bedding	New Source	Gradation	One time	Delivery date
3.2.4	Class 6 Aggregate Base Course	New Source	Gradation	One time	Delivery date
3.2.4	Class 6 Aggregate Base Course	In-place	Compaction	Once a day	End of day
3.2.5	Rip Rap	New Source	Gradation	One time	Delivery date
5.3.2	Geotextile	New Source	Material confirmation	One time	Delivery date
5.3.3	Geomembrane	New Source	Material confirmation	One time	Delivery date
5.4.2	Geomembrane	Installed	Seam tests	See Section 5	End of day
6.2	All Matrix Materials	New Source	Chemical Analysis	One time	Delivery date
6.2.1	Topsoil	New Source	Material confirmation	One time	Delivery date
6.2.2	Rounded Rock	New Source	Gradation	One time	Delivery date

QA/QC Requirements
(continued)

Reference Spec	Material	Condition	Required Test	Frequency	Due Date
6.2.2	Rounded Rock	New Source	Gradation	One time	Delivery date
6.2.2	Wood Chips	New Source	Gradation	One time	Delivery date
6.2.2	Manure	New Source	Material confirmation	One time	Delivery date
6.2.3	Rounded Rock	New Source	Gradation	One time	Delivery date
6.2.4	Limestone Rock	New Source	Gradation	One time	Delivery date
7.2.1	Wood Chips	New Source	Gradation	One time	Delivery date
7.2.1	Wood Shavings	New Source	Gradation	One time	Delivery date
7.2.1	Manure	New Source	Material confirmation	One time	Delivery date
7.2.1	1.5-inch Limestone	New Source	Gradation	One time	Delivery date
7.2.2	3-inch Limestone	New Source	Gradation	One time	Delivery date

SECTION 3 – EARTHWORK

3.0 GENERAL

This section describes the work included in clearing, grubbing, and preparing the project site for construction operations and includes materials, testing, and installation of earthwork for excavations, fills, embankments, roadways, structures, and accessory items at the project site.

3.1 REQUIREMENTS

3.1.1 Submittals

1. Submit excavation and shoring drawings, if applicable, for worker protection in accordance with Occupational Safety and Health Administration (OSHA) standards and Atlantic Richfield (AR) Remediation Management (RM) Control of Work (CoW) Requirements.

2. Submit four copies of a report from a testing laboratory, verifying that the fill materials conform to the gradation specified.

3. Submit copies of compaction reports, as specified herein and in Section 1.

4. Submit dewatering plan.

3.1.2 Clearing and Grubbing

1. Remove and dispose of metal and concrete debris, trees, wood, or root matter, including grass, stumps, logs, trunks, roots, or root systems greater than 1 inch in diameter or thickness to a depth of 12 inches below the ground surface.

2. All collected material shall be disposed of at an off-site legal disposal site. Any suitable topsoil materials shall be segregated and stockpiled on site at a location to be coordinated with the Owner's Representative.

3.1.3 Testing for Compaction

The Contractor shall test for compaction and relative density as described below.

1. Determine the density of soil in place by the sand cone method, ASTM D1556, or by nuclear methods, ASTM D6938. Compaction tests will be performed for each lift or layer.

2. Determine laboratory moisture-density relations of soils per ASTM D1557.

3. Sample materials per ASTM D75.

4. "Relative compaction" is a ratio expressed as a percentage of the in-place dry density to the laboratory maximum dry density.

5. Compaction shall be performed on each lift and deemed to comply with the technical specifications when no test falls below the specified relative compaction. Each test shall be no more than three percentage points below the specified compaction.

3.1.4 Disposal of Excess Material

Excess site excavated or wasted material shall be disposed of on site by the Contractor at a location coordinated with the Owner's Representative.

3.1.5 Material Availability

Sufficient earthwork material to complete the work is not available at the site. Secure source of material(s) and permits to complete the project requirements. Obtain fill and backfill material from off site, as necessary, to satisfy project requirements.

3.2 MATERIALS

3.2.1 Fill

1. Fill material is material that is to be placed in locations that are not to be constructed as structural fill.

2. Fill shall be excavated material that is free from organic matter (including peat and humus), roots, debris, sludge, frozen materials, and rocks larger than 6 inches in the greatest dimension. Large debris and rocks must be removed from fill prior to placement.

3. Imported fill shall consist of silty sand and gravel with 5 percent (%) to 35% fines (finer than the No. 200 sieve) by weight and approximately 10% to 50% gravel (coarser than the No. 4 sieve) by weight, with no material larger than 3-inch diameter. The source and material of imported fill (borrow material) shall be submitted to the Engineer and approved in writing prior to purchase, hauling, and placement.

3.2.2 Structural Fill

1. Structural fill is material that is to be placed beneath structures to the limits indicated in the Construction Drawings and placed under sections of high-density polyethylene (HDPE) geomembrane where over excavation has occurred.

2. Structural fill shall be excavated material that is free from organic matter (including peat and humus), roots, debris, calcines, sludge, frozen materials, and rocks larger than 3 inches in the greatest dimension. Large debris and rocks must be removed from fill prior to placement.

3. Imported structural fill shall consist of silty sand and gravel with 5% to 35% fines (finer than the No. 200 sieve) by weight and approximately 2% to 30% gravel (coarser than the No. 4 sieve) by weight, with no material larger than 3-inch diameter. The source and material of imported fill (borrow material) shall be submitted to the Engineer and approved in writing prior to purchase, hauling, and placement.

3.2.3 Pipe Bedding

Granular sand and gravel bedding for piping shall consist of well-graded sand and gravel with a maximum size of ¾ inch, an average size of No. 4 sieve, and less than 10% passing a No. 200 sieve, by weight.

3.2.4 Class 6 Aggregate Base Course

Backfill shall consist of Class 6 aggregate base course, per Colorado Department of Transportation (CDOT) specifications. Class 6 aggregate base shall be used in the access roadway.

3.2.5 Rip Rap

Erosion protection shall be placed at the pipe outfalls into Pond 18. Erosion protection shall consist 100% of sound 6-inch to 8-inch angular rock.

3.2.6 Water for Compaction and Dust Control

The Contractor shall provide all water, piping, and conveyance/transportation methods from the source to the point of use as needed for earthwork and dust control. Water from the St. Louis Tunnel discharge channel or from site ponds is not suitable for use. The water source shall be coordinated with the Owner's Representative for point of diversion and diversion quantities. A permit is currently in place with the Dolores Water Conservancy District.

3.2.7 Calcines

1. Calcines consist of red or purple colored fine grain material, as confirmed by Owner's Representative or the Engineer.

2. If it is determined by the Engineer in the field that calcines left in place as subgrade material are structurally sound (can be compacted to the specified 95% of the Standard Proctor Dry Density), they may be left in place.

3. Excavated calcines shall not be used for backfill material where calcines did not previously exist and must be stockpiled on site in a location coordinated with the Owner's Representative or Engineer.

3.2.8 Sludge

Pond sludge includes fines and organic materials not suitable for backfill. Sludge material must be stockpiled on site in a location coordinated with the Owner's Representative.

3.3 EXECUTION

3.3.1 Site Grading

Perform earthwork to the lines and grades shown in the Construction Drawings. Shape, trim, and finish slopes of channels to conform to the lines, grades, and cross sections as shown. Do not over excavate and backfill to achieve the proper grade.

3.3.2 Excavation

1. The site shall be graded per the Construction Drawings. Drainage features shall be temporarily installed during construction to divert run-on drainage into area of work or completed work and to mitigate ponding of stormwater during construction. Excavation shall be performed in accordance with OSHA standards and AR RM CoW Requirements.

2. Suitable materials shall be hauled and stockpiled on site after excavation. The stockpile location shall be coordinated with the Owner's Representative prior to commencement of excavation. No material may leave the site.

3. If the base of any excavation is unsuitable due to soil moisture, debris, or pond sludge, the base material shall be over excavated to remove unsuitable material, and the over excavated volume shall be replaced with structural fill. If the excavation base material is still unsuitable after 2 feet of over excavation, the contractor can continue to excavate until competent material is reached, or the use of geotextile soil reinforcement can be used, as detailed in Section 5 – Geotextile and Geomembrane Liner.

3.3.3 Backfill

Place in maximum 8-inch loose lifts and compact each lift to 85% of the standard proctor. Backfill in pipe trenches shall be placed in 8-inch lifts and each lift compacted to 90% of the standard proctor.

3.3.4 HDPE Geomembrane

1. The finished subgrade shall be within a tolerance of ±0.10 foot of the grade and cross section indicated or as approved by the Engineer.

2. Existing subgrade and any structural fill placed under the geomembrane shall be compacted to 95% of the standard proctor.

3.3.5 Hydraulic Structures

1. The finished subgrade shall be within a tolerance of ±0.10 foot of the grade and cross section indicated or as approved by the Engineer. In areas containing rock, finish subgrade tolerance shall be coordinated with the Engineer.

2. Place 12 inches of structural fill under hydraulic structures in 6-inch lifts and compact the top 12 inches of the subgrade to 95% of the standard proctor.

3.3.6 Pipe Bedding

Pipe bedding shall be placed according to the trench detail in the Construction Drawings. Bedding material shall be compacted using hand operated tamping equipment. Bedding shall be placed 1 foot above the center of pipe before trench backfilling begins. A vibratory plate compactor is acceptable from 1 foot above the center of pipe to 3 feet above the center of pipe. No heavy construction machines shall be permitted over piping until a minimum of 3 feet of compacted backfill has been placed over piping.

3.3.7 Moisture Control and Dust Control

1. During soil compaction, the Contractor shall maintain optimum practicable moisture content required during placement and compaction in each lift. At the time of compaction, the water content of the material shall be at optimum water content or within 2% of optimum.

2. Contractor shall provide dust control during excavation, as necessary, to reduce airborne dusts and calcines. Calcine work shall be conducted within a restricted work zone with appropriate health and safety protocols in place.

3.3.8 Class 6 Aggregate Base Course

1. Class 6 aggregate base course shall be placed in 6-inch lifts.

2. Moisture conditioning may be required, and water shall be added or material scarified to condition the material to within 2% of the optimum moisture content prior to compaction.

3. Compaction shall be performed to 95% of the standard proctor.

3.3.9 Rip Rap

Erosion protection rock shall be dumped in place and spread to match the existing slope. No special placement or density is required.

SECTION 4 – PIPE, FITTINGS, VALVES, APPURTENANCES, AND HYDRAULIC CONTROL STRUCTURES

4.0 GENERAL

1. This section describes the general requirements for selecting piping materials and miscellaneous piping items.

2. This section includes materials, testing, and installation of manually operated valves including gate and ball valves.

3. This section also shall apply to wetland demonstration project water conveyance pipe, storm drain pipe, and hydraulic structures.

4.1 REQUIREMENTS

Piping, valves, flowmeters, mixers, etc. shall be installed in locations identified in the Construction Drawings. Hydraulic control structures such as inlet boxes, outlet boxes, Agridrains (weirs), and perforated pipe shall be located in accordance with the Construction Drawings.

4.1.1 Submittals – Piping and Fittings

1. Submit shop drawings in accordance with the technical specifications.

2. Submit manufacturer's data sheets for all polyvinyl chloride (PVC) piping, fittings, appurtenances, and equipment to be used.

3. Submit manufacturer's data sheets on proposed cleaning chemicals, solvent, and cement proposed for use, including Material Safety Data Sheets.

4. Submit manufacturer's data sheet for gaskets.

4.1.2 Submittals – Valves

Submit valve manufacturer's catalog data and descriptive literature in accordance with technical specifications.

4.2 MATERIALS

1. Pipe less than 4 inches in diameter shall be Schedule 80 PVC. Fittings for piping up to 4 inches in diameter shall be Schedule 80 PVC. Fittings shall be Schedule 80 PVC and shall be socket-type fittings, except where flanged joints are required to connect to valves and equipment.

2. Solid pipe 6 inches in diameter shall be Schedule 40 PVC. Perforated 6-inch diameter pipe shall be Schedule 40 PVC. Fittings shall be Schedule 40 PVC and shall be socket-type fittings.

3. Sixteen-inch and 18-inch pipe shall be Schedule 40 PVC. Fittings shall be Schedule 40 PVC and shall be socket-type fittings.

4. PVC flanges shall be Class 150 bolt pattern and one-piece solid socket design and shall be the same schedule type as the pipe. Do not use Van Stone flanges.

5. Unions shall have socket-type ends and shall match the schedule type of piping where they are to be installed.

6. Valves shall be as indicated in Construction Drawings. Vented ball valves shall be used for flow isolation. Gate valves shall be used for flow control. Provide with operating hand wheels or levers, operating nuts, and extension stems, as required. All valves should match the schedule rating of the pipe where they are to be installed.

7. Flowmeters shall be 2-inch diameter electromagnetic Toshiba Model No. GF63205ANBA1.

8. Static mixers shall be 3-inch diameter Schedule 80 PVC Koflow low pressure loss model.

9. Agridrains, as manufactured by Agri Drain Corporation, shall be provided of the size and locations as shown on the Construction Drawings.

10. Twelve-inch diameter drainage culverts shall be constructed from dual wall corrugated exterior HDPE (ADS N-12) pipe. Pipe connections shall be integral bell and gasket joints.

4.3 EXECUTION

4.3.1 Piping and Valves, General

1. Pipe trenching shall be executed per Section 3 – Earthwork.

2. Pipe placement and backfill materials shall conform to the pipe trench detail in the Construction Drawings.

3. Compact material placed within 12 inches of the outer surface of the pipe by hand tamping only.

4. Pipe with less than 6 feet of cover (excluding culverts) must have insulation, per the trench detail in the Construction Drawings. Insulation shall be placed as the trench is backfilled.

5. Pipe invert elevations must be within ±0.10 foot of the design elevation in the Construction Drawings.

6. Piping must be leak tested prior to backfill.

7. Test valves for leakage at the same time that the connecting pipelines are tested. Valves shall show zero leakage. Repair or replace any leaking valves and retest.

8. Operate manual valves through three full cycles of opening and closing. Valves shall operate from full open to full close without sticking or binding. Do not backfill buried valves until verifying that valves operate from full open to full closed.

9. Vented ball valves shall be installed such that the drilled hole (i.e., vent) in the ball points in the direction of flow. Confirm, mark the flow orientation on the valve, and install accordingly.

10. In flow control boxes, provide a minimum of two 12-inch long, 4-inch by 4-inch redwood sleepers to support the piping.

4.3.2 Flowmeter

Flow metering equipment shall be installed in accordance with the details and installation notes provided on the Construction Drawings.

Provide a Grip L Coupling by Straub (or equivalent) downstream of the flowmeter. Coupling shall be installed in locations shown on Construction Drawings. Tighten the coupling per the manufacturer's specifications. Leak test the connection as required by manufacturer to ensure leak-proof connection.

4.3.3 Agridrains

Agridrains shall be installed on compacted structural backfill, as detailed for hydraulic structures in Section 3 – Earthwork.

4.4 LEAK TESTING

4.4.1 Piping

1. Perforated pipe and culverts do not require leak testing.

2. All non-perforated PVC pipe shall be leak tested using a low pressure air test with pneumatic plugs at either end of the pipe segment.

    a. One of the plugs provided shall have two taps. One tap will be used for introducing air into the pipeline through suitable valves and fittings so that the input air may be regulated. The second tap shall be fitted with valves and fittings to accept a pressure gauge to monitor the internal pressure of the pipe.

    b. The pressure gauge shall be 4.5 inches in diameter, with bourdon tube or diaphragm, 0 pounds per square inch (psi) to 15 psi pressure range, a 1 psi figure interval, and 0.05 psi minor increments.

3. The leak testing procedure shall be as follows.

    a. Connect the pressure gauge and air control equipment to the proper fittings, and slowly apply air pressure.

b. Pressurize the pipe line to 4.0 psi gauge (psig), and throttle the air supply to maintain between 3.5 psig and 4.0 psig for at least two minutes in order to allow equilibrium between air temperature and pipe walls.

c. During this time, check all plugs for leakage.

d. If plugs are found to leak, bleed off air, tighten plugs, and repressurize the pipeline.

e. After the temperature has stabilized, allow the pressure to decrease to 3.5 psig.

f. At 3.5 psig, begin timing to determine the time required for pressure to drop to 2.5 psig.

g. The time, in seconds, for the air pressure to drop from 3.5 psig to 2.5 psig should be greater than 18 seconds per 100 feet of pipe tested.

h. If the air test fails to meet this time requirement, the leak shall be located and repaired, and the pipeline shall be retested until the leakage is within the allowable limits.

4.4.2 Hydraulic Structures and Agridrains

Hydraulic structures (excluding storm drain manholes and inlets) and Agridrains shall be leak tested by performing a hydrostatic leak test. The leak testing procedure shall be as follows.

1. The inlet and outlet of the structure shall be sealed with watertight plugs or bulkheads, and the structure shall be filled with water to within 6 inches of the top/rim.

2. The test level shall be clearly marked in the structure.

3. The test shall last a minimum of 24 hours. Once the test begins, the structure's lid shall be removed only in the presence of the Engineer.

4. Exfiltration will be determined by measuring the amount of water required to raise the water level back to the marked level at the end of the test period.

5. The structure shall be considered to pass the water exfiltration test if the exfiltration volume is less than 0.3 gallon per 100 gallons of volume in the structure during the test or if the water level decreased less than 1/8 inch over the test period, whichever is less.

6. If the structure fails the water exfiltration test, the structure shall be repaired with a method approved by the Engineer or completely replaced.

7. The water exfiltration test shall be repeated until a satisfactory test is obtained.

8. All temporary plugs shall be removed after each test.

SECTION 5 – GEOTEXTILE AND GEOMEMBRANE LINER

5.0 GENERAL

1. This section includes materials, installation, and testing of a waterproof HDPE geomembrane for installation in the wetland demonstration project.

2. The basins each shall be lined with two (2) layers of geotextile and one (1) layer of geomembrane, per the Construction Drawings. Refer to Section 3 – Earthwork.

3. The purpose of the work shall be to provide a stabilized working platform section on which wetland geotextile fabrics, geomembrane , and matrix materials can be placed over otherwise unstable (i.e., soft) materials. This technical specification shall be used for a construction platform and not as a means of mitigating swell.

5.1 REQUIREMENTS

Submittals shall include the following.

1. Submit shop drawings in accordance with the technical specifications.

2. Submit manufacturer's catalog data and descriptive literature. Show lining thickness.

3. Submit sheet layout with proposed size, number, and position of factory-fabricated sheets, and indicate the location of factory and field joints. Show complete details and/or methods for anchoring the lining at top of slope, making field joints, and making seals at structures, pipes, etc. The layout must be approved by the Engineer prior to commencing the work.

4. The installer of the flexible membrane liner material shall be approved in writing by the manufacturer prior to installing the liner material. Manufacturer shall submit this written approval to the Owner's Representative or Engineer prior to commencement of any work on the liner.

5. Submit a material sample and weld sample.

6. Additional data, as indicated elsewhere in this technical specification.

5.2 MATERIALS

5.2.1 Reinforcement Grade Woven Geotextile

5.2.1.1 Delivery, Storage, and Handling

1. Geotextile labeling, shipment, and storage shall follow ASTM D4873.

2. Product labels shall show clearly the manufacturer or supplier name, style name, and roll number.

3. Each geotextile roll shall be wrapped with a material that will protect the geotextile from damage due to shipment, water, sunlight, and contaminants.

4. During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following.

    a. Site construction damage

    b. Precipitation

    c. Extended ultraviolet (UV) radiation including sunlight

    d. Chemicals that are strong acids or strong bases

    e. Flames including welding sparks

    f. Excess temperatures

    g. Any other environmental conditions that may damage the physical property values of the geotextile

5.2.1.2 Subgrade Geotextile

1. Reinforcement subgrade geotextile shall be woven from high-tenacity, long-chain, synthetic polymers composed of at least 95% by weight polyolefins or polyesters. They shall form a stable network such that the filaments or yarns retain their dimensional stability relative to each other, including selvages.

2. The geotextile shall meet the requirements of the following table. All numeric values in the table except Apparent Opening Size (AOS) represent minimum average roll values (MARV) in the specified directions. Values for AOS represent maximum average roll values.

Subgrade Stabilization Geotextile (Mirafi HP 570)

Property	Test Method	Units	Required Value	
Reinforcement Properties			**MD**	**CD**
Tensile Strength @ Ultimate	ASTM D4595	lbs/ft (kN/m)	4800 (70)	4800 (70)
Tensile Strength @ 2% Strain	ASTM D4595	lbs/ft (kN/m)	960 (14)	1320 (19.3)
Tensile Strength @ 5% Strain	ASTM D4595	lbs/ft (kN/m)	2400 (35)	2700 (39.4)
Coefficient of Interaction (Ci; sand)	ASTM D5321	-	0.8	
Permittivity	ASTM D4491	sec^{-1}	0.4	
Apparent Opening Size	ASTM D4751	U.S. Sieve (mm)	30 (0.6)	
Sewn Seam Strength [1]	ASTM D4884	lbs/ft (kN/m)	3000 (43.8)	
Survivability Index Values			**MD**	**CD**
Grab Tensile Strength	ASTM D4632	lbs (N)	475 (2114)	440 (1958)
Tear Strength	ASTM D4533	lbs (N)	180 (801)	180 (801)
CBR Puncture Strength	ASTM D6241	lbs (N)	2000 (8900)	
Ultraviolet Stability (after 500 hours)	ASTM D4355	%	80	

1. When sewn seams are required. Refer to Execution for overlap/seam requirements.

5.2.1.3 Subgeotextile

Mirafi HP 570 or equivalent.

5.2.2 Geotextile

1. The materials supplied as non-woven geotextile shall be of new, first-quality (needle-punched, heat- or spun-bound, or stapled) polymer of 100% polyethylene or polypropylene (97% polypropylene and 3% carbon black with antioxidants and heat stabilizers) or polyester/polypropylene blend designed and manufactured specifically for the purpose of separation, tensile reinforcement, planar flow, and filtration and shall be used as designated on the Construction Drawings. The non-woven geotextile shall have a mass per unit area of 12 ounces per square yard (oz/yd^2) unless otherwise designated on the Construction Drawings.

2. The materials shall be produced to be free of holes, undispersed raw materials, broken needles, or any sign of contamination by foreign matter. The geotextile fabric shall be uniform in color, thickness, size, and texture, and all rolls shall be properly tagged and identified by the manufacturer with the manufacturer's name, product identification, roll number, roll identification, and other pertinent information to fully describe the geotextile.

3. The manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of this technical specification. Documentation describing the quality control program shall be made available upon request. Testing shall be performed in accordance with the methods referenced in this technical specification. The manufacturer's certificate shall state that the finished geotextile meets the requirements of the technical specification. Either mislabeling or misrepresentation of materials shall be reason to reject those geotextile products.

4. The material supplied as non-woven geotextile shall conform to the standards outlined in the following table.

Non-Woven Geotextile

Properties		ASTM Test Method	Value [a]			Minimum Test Frequency (1 per)
Mass per unit area, oz/yd²	D5261	6	8	10	12	90,000 ft²
Grab tensile strength, lbs	D4632	170	220	260	320	90,000 ft²
Grab elongation, %	D4632	50	50	50	50	90,000 ft²
Puncture strength, lbs	D4833	110	135	180	210	90,000 ft²
Mullen burst strength, psi	D3786	330	420	520	620	90,000 ft²
Trapezoidal tear strength, lbs	D4533	70	95	100	125	90,000 ft²
Apparent opening size, sieve #	D4751	70	80	100	100	540,000 ft²
Permeability, cm/s	D4491	0.30	0.30	0.30	0.29	540,000 ft²
Water flow rate, gpm/ft²	D4491	110	110	85	60	540,000 ft²
UV resistance (%) [b]	D4355	70	70	70	70	per formulation

[a] All values are MARV except UV resistance and AOS in mm. Values for AOS represent maximum average roll value. UV is a typical value.
[b] Evaluation to be 2-inch strip tensile specimens after 500 hours of exposure.
[c] Values that represent directional properties are specified for the weaker principal direction.

5. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

6. Each geotextile roll shall be wrapped with a material that will protect the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight, and contaminants.

7. The protective wrapping shall be maintained during periods of shipment and storage.

8. During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following.

    a. Site construction damage

    b. Precipitation

    c. Extended UV radiation including sunlight

    d. Chemicals that are strong acids or strong bases

e. Any other environmental conditions that may damage the property values of the geotextile

5.2.3 Geomembrane Liner

1. The geomembrane shall be textured on both sides, HDPE, 60-mil nominal thickness, unless otherwise designated on the Construction Drawings.

2. The HDPE geomembrane shall be a high quality formulation containing approximately 97% polymer and 3% carbon black with antioxidants and heat stabilizers. It shall be resistant to UV rays. All resin shall be hexene-based, consist of all virgin material from the same manufacturer, shall not be intermixed, and no reclaimed polymer may be added to the resin. The manufacturing process shall not use more than 10% re-work. If re-work is used, it must be similar HDPE to the parent material.

3. The geomembrane material shall be comprised of HDPE material manufactured of new, first-quality products designed and manufactured specifically for the purpose of liquid containment in hydraulic structures, as applied to the mining industry. The material shall be produced to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter. The geomembrane is to be supplied in roll form. Each roll is to be identified with labels indicating roll number, thickness, length, width, and manufacturer's name.

4. The geomembrane manufacturer shall be ISO 9000/2000 certified. The manufacturer's laboratory must be certified by Geosynthetic Accreditation Institute (GAI) / Laboratory Accreditation Program (LAP) for the tests being performed and shall have a third-party independent quality assurance program. The third party shall perform the required tests at the required frequency, as stated in this technical specification, or at such frequency as is mutually agreed to by the Engineer and the manufacturer at the time of award. All test results shall be provided to the Engineer, and the rolls of material shall be clearly identified and correlate to the test results.

5. Extrudate rod or bead material used for extrusion welding shall be made from the same type of resin as the geomembrane and be from the same resin supplier as the resin used for manufacture of the geomembrane.

6. The material shall be warranted against manufacturer's defects as well as degradation due to UV light for exposed areas for a minimum of 20 years from the date of installation or as mutually agreed prior to award of the contract for supply between the Engineer and the geomembrane manufacturer. This warranty shall cover the cost of material, freight and duties, handling, labor, and equipment to replace the defective or failed material.

7. The material supplied shall conform to the standards outlined in the Tables 1, 2, and 3 at the end of this section. The manufacturer shall furnish the following product data, in writing, to the Engineer prior to shipment of the geomembrane material.

a. Resin:

   i. Certification stating that the resin meets the technical specification requirements and that it is all from the same manufacturer.

   ii. Statement certifying no reclaimed polymer is added to the resin.

   iii. Copy of QA/QC certificates issued by resin supplier.

b. Geomembrane roll, extrudate rod, and bead material:

   i. Copy of QA/QC certificates issued by the geomembrane manufacturer and the third-party independent quality assurance tester.

   ii. Certification that the geomembrane material delivered to the project complies with these technical specifications.

   iii. Certification that extrudate rod or bead is from one manufacturer, is the same resin type, and was obtained from the same resin supplier as the resin used to manufacture the geomembrane rolls.

c. Conformance tests shall be conducted using the following ASTM testing methods at a minimum of one sample per resin lot:

60-mil HDPE Textured Geomembrane
ASTM D5994 – Thickness
ASTM D1505 – Density
ASTM D6693 – Tensile Properties
ASTM D4833 – Puncture Resistance
ASTM D1603 – Carbon Content

5.3 EXECUTION

5.3.1 Reinforcement Grade Geotextile Installation

1. Contractor shall check the reinforcement grade woven geotextile upon delivery to verify that the proper material has been received. The geotextile shall be inspected by the Contractor and confirmed to be free of flaws or damage occurring during manufacturing, shipping, or handling.

2. Install reinforcement grade woven geotextile at locations shown on the Construction Drawings or as designated by the Engineer. Two layers of reinforcement grade woven geotextile shall be placed on the compacted subgrade. The two layers shall be oriented to ensure that their principal strength directions are perpendicular to each other.

3. Sewn and overlapped joints shall meet the manufacturer's recommendations for reinforcement over subgrade. Where subgrade is firm, sewing or 36-inch overlapping shall be used for joint connections and tear repair. In wet areas where subgrade is

extremely soft, roll joints or repair joints shall be sewn to meet the sewn strength shown in Section 5.2.1.2.

4. On curves, the geotextile may be folded or cut to conform to the curves. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock.

5. Prior to covering, the geotextile shall be inspected by the Engineer to ensure that the geotextile has not been damaged during installation. Damaged geotextile shall be repaired immediately. Install a patch over a damaged area and extend 3 feet beyond the perimeter of the tear or damage, and sew or overlap patch.

6. A minimum 24-inch thick, 1.5-inch minus sub-round to sub-angular fill shall be placed atop the two layers of geotextile. Sharp rock and objects shall be avoided. At soft or critical locations, another layer of geotextile may be placed in the middle of the 24-inch thick fill, as directed by the Engineer. The bottom 12 inches of fill shall be placed in a single 12-inch lift and compacted to a density equivalent to 95% of the standard proctor. In extremely soft conditions, the lower 12-inch lift may be placed uncompacted. The top 12 inches of fill shall be placed in two 6-inch lifts and compacted to a density equivalent to 95% of the standard proctor.

7. The fill shall be placed by end dumping onto the geotextile from the edge of the geotextile or over previously placed fill. Sudden braking and sharp turning shall be avoided. Tracked construction equipment should not be operated directly upon the geotextile. A minimum fill thickness of 12 inches is required prior to operation of tracked vehicles over the geotextile. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the geotextile. Sharp turning of vehicles shall not be permitted on the first lift above the geotextile.

8. If placement of the backfill material causes damage to the geotextile, the damaged area shall be repaired as previously described. The placement procedure then shall be modified to eliminate further damage from taking place.

5.3.2 Geotextile

1. The non-woven geotextile shall be installed on the areas shown on the Construction Drawings or as directed by the Engineer.

2. The geotextile shall be handled in such a manner as to ensure that it is not damaged in any way.

3. All geotextiles shall be weighted by sandbags or approved equivalent. Such anchors shall be installed during placement and shall remain in place until replaced with cover material.

4. Necessary precautions shall be taken to prevent damage to adjacent or underlying materials during placement of the geotextile. The geotextile shall not be exposed to precipitation prior to being installed and shall not be exposed to direct sunlight for more than 15 days after installation.

5. When seaming is specified, the geotextile shall be seamed using heat seaming or overlap stitching methods as recommended by the geotextile manufacturer and approved by the Engineer. Sewn seams shall be made using polymeric thread with chemical resistance equal to or exceeding that of the geotextile. All sewn seams shall be continuous. Seams shall be oriented down slopes perpendicular to grading contours unless otherwise specified. For heat seaming, fusion-welding techniques recommended by the geotextile manufacturer shall be used.

6. All joints shall have a minimum 6-inch overlap and shall be continuously heat-fused; alternatively, joints may be sewn where they are used to enclose drainage material around a pipe or other structure.

7. Construction equipment should not be operated directly upon the geotextile.

8. Material overlying the geotextile shall be placed carefully to avoid wrinkling or damaging the geotextile.

9. Holes in the geotextile material shall be repaired using a patch of identical material extending a minimum 6 inches on all sides of the hole. The patch shall be heat bonded. If heat bonding is not possible, the patch shall extend a minimum of 18 inches on all sides of the hole.

10. In areas where non-woven geotextile is used as separation or filtration, care should be taken to install the layer without producing holes or gaps where the migration of fines into the drainage system could occur. This may be done by ensuring sufficient overlap of seams (minimum 18 inches) and properly wrapping the edges of the geotextile under the gravel areas being protected or over-running the edges of the geotextile past the area requiring separation or filtration.

5.3.3 Geomembrane Liner

1. The HDPE geomembrane shall be installed on the areas shown on the Construction Drawings or as directed by the Engineer.

2. Prior to deployment of geomembrane, the Installer shall inspect and accept, with the Engineer, all surfaces on which the geomembrane is to be placed. The surface on which the geomembrane is to be installed shall be free of sharp particles, rocks, or other debris to the satisfaction of the Engineer and the Installer. Sharp objects shall be removed by raking, sweeping, or handpicking, as necessary.

3. To the extent possible, field and factory seams shall run perpendicular to the top of the slope. Panels shall be secured temporarily with sandbags or other approved ballasting method to hold them in place until field seams have been completed and the geomembrane has been anchored permanently.

4. Installation of the geomembrane shall be performed under the direction of a field engineer or supervisor who has installed a minimum of 500,000 square feet of flexible geomembrane material. The geomembrane shall be placed over the prepared surfaces using methods and procedures that ensure a minimum of handling. Adequate temporary and permanent anchoring devices and ballasting shall be provided to prevent uplift and damage due to winds. The Installer is solely

responsible for the safety of their operations, including decisions regarding deployment in adverse weather conditions and the amount of temporary anchoring and ballasting required.

5. Use lap joints to seal factory-fabricated sheets of HDPE together in the field with minimum 6-inch overlaps. Make field joints between sheets of HDPE on a supporting smooth surface. Form the lap joints by lapping the edges of sheets a minimum of 6 inches. Wipe the contact surfaces of the sheets clean to remove dirt, dust, moisture, or other foreign materials. Joints shall be extrusion-welded or hot-shoe welded; hot-air welding will not be allowed except as tack-welding prior to final welding. Welds shall be in accordance with the manufacturer's recommendations.

6. Patch repairs to the HDPE membrane with a piece of the membrane material itself. Apply patching with an extrusion weld.

7. Tightly bond joints on completion of the work. Replace or repair any geomembrane surface showing injury due to scuffing, penetration by foreign objects, or distress from other causes with an additional piece of membrane material of the proper size.

8. Anchor the geomembrane to the inside crest edge of the embankment such that no movement or displacement of the geomembrane on the inside embankment face can be realized. This anchoring shall be done following the loading/backfilling the basin/cell.

9. The Installer shall take into account that frequent high winds may result in delays. The Installer shall take all necessary measures to ensure that each panel is sufficiently ballasted to prevent damage or movement by wind. Fusion of panels and repairs will be permitted only under weather conditions allowing such work and within the warranty limits of the geomembrane manufacturer, as approved by the Engineer.

10. Horizontal field seams on slopes shall be kept to a minimum. Horizontal seams on steep slopes shall be avoided where possible by cutting the geomembrane at a 45-degree angle. Generally, horizontal seams are to be no closer than 10 feet from the toe of the slope. Horizontal seams shall be made by lapping the uphill material over the downhill material. Panels shall be shingled in a manner that prevents water from running beneath the geomembrane.

11. The geomembrane shall be installed in a relaxed condition and shall be free of tension or stress upon completion of the installation. The installed geomembrane shall contain sufficient slack material to allow for thermal expansion and contraction. Individual wrinkles should take the form of undulations in the geomembrane but should not be large enough for the material to fold over itself.

12. During installation, the Installer shall give each field panel an identification code number consistent with the layout plan. The Engineer shall agree upon the numbering system. The Installer shall update the layout plan as each panel is installed to show the location of each panel. A field panel is defined as the area of geomembrane that is to be seamed in the field (roll or portion of a roll cut in the field).

13. Individual panels of geomembrane material shall be laid out in a pattern that will produce the least number of seams. The material shall be overlapped prior to welding. Extreme care shall be taken by the Installer in the preparation of the areas to be welded. The joint interface shall be cleaned and prepared according to procedures laid down by the material manufacturer and approved by the Engineer. Seaming shall not take place unless the panel is dry and clean. All sheeting shall be welded together by thermal methods.

14. Any area showing damage due to excessive scuffing, puncture, or distress from any cause shall be replaced or repaired with an additional piece of geomembrane.

15. No “fish mouths” will be allowed within the seam area. Where “fish mouths” occur, the material shall be cut, overlapped, and an overlap extrusion weld applied.

16. Geomembrane panels must have a finished overlap of 4 inches to 6 inches for double-wedge welding seams and minimum 6 inches for extrusion welding seams. Notwithstanding this provision, sufficient overlap shall be provided to allow peel tests to be performed on any seam.

17. Handling and storage of the geomembrane shall be in accordance with the manufacturer’s printed instructions. Persons walking or working on the geomembrane shall not engage in activities or wear shoes that could damage the geomembrane.

18. An adequate number of handling equipment, welding apparatuses, and test equipment shall be maintained on site to avoid delays due to problems with equipment failures.

19. Upon completion of installation, dispose of trash, waste, material, and equipment used in connection with the work hereunder, and leave the premises in a neat condition.

5.4 TESTING

5.4.1 Geotextile

1. The Installer, along with the Engineer, shall be responsible for accepting the subgrade surface prior to deploying the overlying geosynthetics.

2. The Engineer may randomly inspect geotextile before, during, and after (using test pits) installation.

3. Any damaged or defective geotextile (i.e., frayed coating, separated junctions, separated layers, tears, etc.) will be repaired/replaced. Proper replacement shall consist of replacing the affected area by adding 3 feet of geotextile to either side of the affected area.

5.4.2 Geomembrane Liner

5.4.2.1 General

1. The Installer shall submit a copy of their Quality Control Manual to the Engineer prior to the start of installation of any geomembrane. If there are discrepancies between this technical specification and the Installer's Quality Control Manual, the more stringent requirements will apply, unless determined otherwise by the Engineer.

2. The Installer shall be fully responsible for carrying out all quality control tests on the geomembrane and shall do so to the satisfaction of the Engineer and in accordance with this specification and the Installer's Quality Control Manual. On-site physical nondestructive and destructive testing shall be completed on all joints to ensure that watertight uniform seams are achieved on a continuous basis as installation proceeds. At the time of bid submission, details shall be provided by the Installer that set forth the method proposed for both destructive and nondestructive testing of seams. The Engineer shall approve these methods prior to the Installer commending the work. Visual inspection alone is unacceptable.

3. Fusion of panels and repairs will be permitted only under weather conditions allowing work that is in conformance with the technical specifications, within the warranty limits imposed by the manufacturer, and to the approval of the Engineer.

4. At a minimum, the Installer's field installation test program shall consist of periodic visual observations and continuity and strength tests, as defined in the following subsections.

5.4.2.2 Trial Welds

Trial welds shall be completed to verify the performance of the welding equipment and operator prior to performing production welds. No welding equipment or operator shall perform production welds until equipment and operator have successfully completed a trial weld. The following procedures shall be followed for trial welds.

1. Make trial welds under the same surface and environmental conditions as the production welds (i.e., in contact with subgrade and similar ambient temperature).

2. Perform a minimum of two trial welds per day per welding apparatus – one made prior to the start of work and one completed at mid-shift or for every 5 hours of seaming operations.

3. Cut five 1-inch-wide-by-6-inch-long test strips from the trial weld.

4. Quantitatively test specimens for peel adhesion and then for bonded seam strength (shear).

5. Trial weld specimens shall pass when the results shown in Table 3 are achieved in both peel and shear tests and when both of the following are achieved.

a. The break, when peel testing, occurs by Separation in the Plane (SIP) of the sheet, not through adhesion failure separation (AD).

b. The break is ductile.

6. Make appropriate adjustments to welding equipment, methods, etc. and repeat the trial weld, in its entirety, when the trial weld samples fail in either peel or shear, as defined on Table 3, footnote 2.

5.4.2.3 Field Seaming

1. The Contractor shall have at least one master welder who will provide direct supervision over other welders, as necessary.

    a. The welding equipment shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the material to ensure changes in environmental conditions will not affect the integrity of the weld.

    b. The seam area shall be cleaned of dust, mud, moisture, and debris immediately ahead of the welding apparatus.

    c. The seam overlaps shall be aligned consistent with the requirements of the welding equipment being used. A 4-inch to 6-inch overlap shall be used for double wedge welded seams and 6-inches for extrusion welded seams unless approved otherwise by the Engineer.

    d. Seaming shall not proceed when the ambient air temperature or adverse weather conditions jeopardize the integrity of the geomembrane installation. The Installer and Engineer shall confer on the determination of this condition.

    e. Extrusion welding apparatus shall be purged of heat-degraded extrudate before welding.

    f. The double-wedge fusion welding process shall be used unless alternate methods are approved by the Engineer. Extrusion welding will be permitted to weld short seams and repair small areas where double-wedge welding is not feasible and where test samples have been removed.

2. The Installer shall perform visual inspections of deployed and welded HDPE panels to identify defects, damage, or protrusion of sharp objects that may affect the integrity of the geomembrane. Defective or damaged areas will be marked and repaired according to the technical specifications and the guidelines in the Installer's Quality Control Manual.

3. A quality control technician or field engineer acting for the Installer shall inspect each seam, marking his initials and date inspected at the end of each panel. Any area showing a defect shall be marked and repaired in accordance with the applicable repair procedures.

5.4.2.4 Continuity Testing

1. A maximum effort shall be made to install a perfect geomembrane. This implies that all seams completed in the field, patches, and extrusions shall be tested and recorded. All failures shall be isolated and repaired as directed by the Engineer. A general testing procedure is included as follows.

    a. Test all field seams and patches with interseam pressure, vacuum box, spark tester, or other approved methods. Pressure and vacuum testing are discussed in following subsections.

    b. Isolate and repair all areas indicating any leakage. Retest the repair.

2. *Interseam Pressure Testing* – test procedure for interseam pressure for seams (for double-wedge welding only):

    a. Seal both ends of the seam to be tested by applying heat to the end of the seam via a heat gun until flow temperature is achieved. Clamp off the ends and let cool.

    b. Insert a pressure gauge/needle assembly into the end of the seam and seal.

    c. Pressurize the air channel between the two seams to between 30 psi and 35 psi. Following pressure stabilization, take the initial pressure reading, hold the pressure a minimum of 3 minutes, and take a second reading.

    d. The allowable leak down for the seam is 3 psi.

    e. If the pressure does not drop below the maximum allowable 3 psi, open the air channel at the end away from the pressure gauge. Air should rush out and the pressure gauge should register an immediate drop in pressure, indicating that the entire length of seam has been tested. If this does not happen, either the air channel is blocked or the equipment is faulty, and the test is not valid.

    f. Enter the results of the leak test on the appropriate document, indicating either a passed or a failed seam. If the seam fails, the repair work and subsequent testing should be recorded on the same document.

    g. Repair the area where the pressure gauge/needle assembly was installed and where the air was released.

3. *Vacuum-Box Testing* – the proposed test procedure is as follows:

    a. Mix a solution of liquid detergent and water and apply an ample amount to the area to be tested. If a seam contains excess overlap or loose edges, it must be trimmed before testing.

    b. Place a translucent vacuum box over the area and apply a slight amount of downward pressure to the box to seat the seal strip to the geomembrane.

c. Apply a vacuum of 3 psi to 5 psi for a minimum of 15 seconds to the area. Any leaks will become visible by large bubbles.

d. Enter the results of the leak test on the appropriate document, indicating either a passed or a failed seam. If the seam fails, the repair work and subsequent testing should be recorded on the same document.

4. *Spark Testing* – extrusion welded patches, cap, etc., in lieu of being vacuum-box tested, may be "spark" tested. The basic procedure for spark testing is as follows.

   a. The seam shall be prepared for extrusion welding in accordance with the Installer's procedures.

   b. Just prior to applying the extrusion bead, a small-gauge copper wire is placed into the seam. An 18-gauge bare copper wire usually works well. The wire should be grounded at one end and placed at the edge of the top sheet of the overlap seam. Tucking the wire under the edge of the top sheet will help hold the wire in place during welding, but this should be done prior to grinding to avoid the risk of contamination of the weld area.

   c. Apply the extrudate bead as normal, and allow the weld to cool.

   d. Energize the spark tester, and move the electrode wand near a grounding source to determine the maximum length of spark that can be generated. Adjust the output voltage setting until the spark length exceeds the greatest potential leak path distance. This is typically the diagonal distance from the embedded wire to the edge of the weld bead at a "T" joint.

   e. Once the output voltage has been set, testing may start. Testing is performed by passing the electrode over the seams with the electrode in contact with the membrane and/or the extruded weld bead. The audible and visual indication of a spark provides the determination of a potential leak path.

   f. If a potential leak is detected, the area may be repaired by grinding and re-welding. Applying additional weld beads adjacent to the leaking weld is not an acceptable repair technique. This will only lengthen the leak path to the extent that the spark tester may not be capable of generating a spark of sufficient length to breach the lengthened gap.

   g. After grinding and re-welding, the seam must be retested. If there is still an indication of a potential leak (spark), it may be required to apply a patch over the entire area.

5.4.2.5 Destructive Testing

1. Peel and shear seam strength testing shall be carried out on samples of seams removed from the installed panels. For these tests, the following procedure shall be followed.

   a. Coupon sampling of all field seams, including patches and repair areas, shall be taken by cutting perpendicular to the seams a sample approximately

36 inches by 12 inches in size. This sample shall be cut into three 12-inch by 12-inch samples, labeled with the date and location, and individually marked "Engineer Sample," "QA/QC Sample," and "Lab QA/QC Sample." The frequency and location shall be determined by the Engineer but shall not be less than one sample per 500 feet of field seams. These coupons shall be tested on site for peel and shear seam strength and thickness, in accordance with D6392.

b. Heat-welded seams shall be allowed to cool or warm to about 70°F prior to testing. Solvent seams, when used, shall be allowed to cure according to the manufacturer's recommendations. Additionally, at the Engineer's option, approximately 10% of the coupons (sized to 1 inch by 6 inches) shall be sent to an independent laboratory for confirmation testing. Should the lab and field tests conflict, installation shall halt until the conflict is resolved to the satisfaction of the Engineer.

2. The Engineer will continuously inspect the installation of the HDPE geomembrane to ensure that the procedures specified in this section are adhered to fully.

3. Weld specimens shall pass when the results shown in Table 3 are achieved in both peel and shear tests and as follows.

    a. The break, when peel testing, occurs by SIP of the sheet not through AD.

    b. The break is ductile.

4. In the event of a failing test result, the Installer shall follow one of the following two options.

    a. Reconstruct the seam between any two passed test locations.

    b. Trace the weld to an intermediate location at least 10 feet or to where the seam ends in both directions from the location of the failed test. Once the failing limits of the seam are isolated, that portion of the seam shall be reconstructed or capped.

5. Seams welded prior to and after the failed seam using the same welding device and/or operator shall be tested.

5.4.2.6 Repair Procedures

Damaged or defective geomembrane or seam areas failing a destructive or non-destructive test shall be repaired. The Installer shall be responsible for repair of damaged or defective areas. The repair method shall be decided by the Installer but must be agreed upon by the Engineer. Procedures available include the following.

1. *Replacement*: Remove damaged geomembrane or unacceptable seam and replace with acceptable geomembrane materials if damage cannot be satisfactorily repaired.

2. *Patching*: Used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.

3. *Abrading and Re-Welding*: Used to repair small seam sections.

4. *Capping*: Used to repair large lengths of failed seams.

5. *Flap Welding*: Used to extrusion-weld the flap (excess outer portion) of a fusion weld in lieu of a full cap.

6. In addition, the following procedures shall be observed.

    a. Surfaces of HDPE that are to be repaired by extrusion welds shall be abraded lightly to ensure cleanliness.

    b. All geomembrane shall be clean and dry at the time of repair.

    c. Extend patches or caps at least 6 inches for extrusion weld and 4 inches for wedge weld beyond the edge of the defect, and round the corners of patch material. The edges of all patches are to be beveled.

7. Furthermore, repair verification shall be performed as follows.

    a. Number and log each patch repair.

    b. Non-destructively test each repair using methods specified in this technical specification.

5.4.2.7 Field Testing of Seam Welders

1. Prior to starting field installation of the geomembrane , each seam welder shall prepare three test strips, each a minimum of 20 feet long. Test six coupons from each strip to failure for both shear and peel. Do not install geomembrane without first successfully passing these initial field tests. Each seam welder shall demonstrate the ability to consistently make successful seams.

2. At the beginning of each day, each welder and welder apparatus shall prepare a 10-foot-long test strip. Test each sample weld for shear and peel. The sample weld shall pass these tests before either the welder or welding apparatus is used on the lining system.

5.4.2.8 Field Testing of Seams

1. Test every weld in the field with a vacuum suction box. Apply a soap solution over the seam weld. When suction is applied to the seam, leaks are demonstrated by bubble formation. Mark and repair all holes.

2. Remove test samples (coupons), and test using an on-site tensiometer.

    a. Test a minimum of one seam sample for each 200 lineal feet of seam fabricated for this project for shear and peel. Repair each hole created by coupon removal.

b. Mark all samples so that they can be identified with the particular group of material from which they are collected.

c. Failure of any sample to meet or exceed the requirements in this technical specification will be cause for rejection of the material from which the failed sample was collected. If the manufacturer can establish to the Engineer, via submittal of additional samples, that only a portion of the material represented by the failed sample does not meet the requirements, then only that portion will be rejected.

5.4.2.9 Certification

At the completion of the geomembrane installation, the Installer shall provide the Engineer with a certification stating that the geomembrane was installed and tested in accordance with the technical specifications together with a report of the test results. The certification shall be provided to the Engineer prior to the demobilization of the installation personnel from the site, unless agreed otherwise by the Owner's Representative. The report of the test results shall be provided in hard copy and digital format to the Owner's Representative and the Engineer not later than 30 days after the installation work has been completed.

5.4.2.10 Completion

At the completion of the installation, the Installer shall provide a set of as-built drawings showing the actual geomembrane panel layout, seams, location(s) of destructive test samples, and location(s) of major repairs, including repaired seams and capped areas. The as-built panel layout must be submitted in hard copy and digital format to the Engineer not later than 30 days after the installation work has been completed.

Table 1 – HDPE Geomembrane, Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. avg.)	D5199	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Per roll
▪ Lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density mg/L (min.)	D1505/D792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lbs
Tensile Properties (min. avg.) [1]	D6693 Type IV								20,000 lbs
▪ Yield strength		63 lbs/in	84 lbs/in	105 lbs/in	126 lbs/in	168 lbs/in	210 lbs/in	252 lbs/in	
▪ Break strength		114 lbs/in	152 lbs/in	190 lbs/in	228 lbs/in	304 lbs/in	380 lbs/in	456 lbs/in	
▪ Yield elongation		12%	12%	12%	12%	12%	12%	12%	
▪ Break elongation		700%	700%	700%	700%	700%	700%	700%	
Tear Resistance (min. avg.)	D1004	21 lbs	28 lbs	35 lbs	42 lbs	56 lbs	70 lbs	84 lbs	45,000 lbs
Puncture Resistance (min. avg.)	D4833	54 lbs	72 lbs	90 lbs	108 lbs	144 lbs	180 lbs	216 lbs	45,000 lbs
Stress Crack Resistance [2]	D5397 (Appendix)	300 hours	300 hours	300 hours	300 hours	300 hours	300 hours	300 hours	Per GRI-GM10
Carbon Black Content (range)	D1603 [3]	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lbs
Carbon Black Dispersion	D5596	Note 4	Note 4	Note 4	Note 4	Note 4	Note 4	Note 4	45,000 lbs
Oxidative Induction Time (OIT; min. avg.) [5]									200,000 lbs
a) Standard OIT	D3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
--OR--									
b) High Pressure OIT	D5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C [5, 6]	D5721								Per each formulation
a) Standard OIT (min. avg.) – % retained after 90 days	D3895	55%	55%	55%	55%	55%	55%	55%	
--OR--									
b) High Pressure OIT (min. avg.) – % retained after 90 days	D5885	80%	80%	80%	80%	80%	80%	80%	

Table 1 – HDPE Geomembrane, Smooth (continued)

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
UV Resistance [5]	GM11								Per each formulation
a) Standard OIT (min. avg.) [7]	D3895	N.R.[7]	N.R.[7]	N.R.[7]	N.R.[7]	N.R.[7]	N.R.[7]	N.R.[7]	
--OR--									
b) High Pressure OIT (min. avg.) – % retained after 1,600 hours [8,9]	D5885	50%	50%	50%	50%	50%	50%	50%	

1. Machine direction (MD) and cross-machine direction (XMD) average values should be on the basis of five (5) test specimens in each direction.
   - Yield elongation is calculated using a gauge length of 1.3 inches.
   - Break elongation is calculated using a gauge length of 2.0 inches.
2. P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
3. Other methods, such as D4218 (muffle furnace) or microwave methods, are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
4. Carbon black dispersion (only near spherical agglomerates) for ten (10) different views: nine (9) in Categories 1 or 2 and one (1) in Category 3.
5. The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
6. It is also recommended to evaluate samples at 30 and 60 days to compare with the 90-day response.
7. Not recommended since the high temperature of the Standard OIT test produces an unrealistic result for some of the antioxidants in the UV-exposed samples.
8. The condition of the test should be 20-hour UV cycle at 75°C followed by 4-hour condensation at 60°C.
9. UV resistance is based on percent-retained value regardless of the original High Pressure OIT value.

Table 2 – HDPE Geomembrane, Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. avg.)	D5994	Nominal (-5%)	Nominal (-5%)	Nominal (-5%)	Nominal (-5%)	Nominal (-5%)	Nominal (-5%)	Nominal (-5%)	Per roll
▪ Lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Asperity Height mils (min. avg.) [1]	GM 12	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	Every 2nd roll [2]
Density mg/L (min.)	D1505/D792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lbs
Tensile Properties (min. avg.) [3]	D6693 Type IV								20,000 lbs
▪ Yield strength		63 lbs/in	84 lbs/in	105 lbs/in	126 lbs/in	168 lbs/in	210 lbs/in	252 lbs/in	
▪ Break strength		45 lbs/in	60 lbs/in	75 lbs/in	90 lbs/in	120 lbs/in	150 lbs/in	180 lbs/in	
▪ Yield elongation		12%	12%	12%	12%	12%	12%	12%	
▪ Break elongation		150%	150%	150%	150%	150%	150%	150%	
Tear Resistance (min. avg.)	D1004	21 lbs	28 lbs	35 lbs	42 lbs	56 lbs	70 lbs	84 lbs	45,000 lbs
Puncture Resistance (min. avg.)	D4833	54 lbs	72 lbs	90 lbs	108 lbs	144 lbs	180 lbs	216 lbs	45,000 lbs
Stress Crack Resistance [4]	D5397 (App.)	300 hours	300 hours	300 hours	300 hours	300 hours	300 hours	300 hours	Per GRI-GM10
Carbon Black Content (range)	D1603 [5]	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lbs
Carbon Black Dispersion	D5596	Note 6	Note 6	Note 6	Note 6	Note 6	Note 6	Note 6	45,000 lbs
Oxidative Induction Time (OIT; min. avg.) [7]									200,000 lbs
a) Standard OIT	D3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
--OR--									
b) High Pressure OIT	D5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C [7, 8]	D5721								Per each formulation
a) Standard OIT (min. avg.) – % retained after 90 days	D3895	55%	55%	55%	55%	55%	55%	55%	
--OR--									
b) High Pressure OIT (min. avg.) – % retained after 90 days	D5885	80%	80%	80%	80%	80%	80%	80%	

Table 2 – HDPE Geomembrane, Textured (continued)

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
UV Resistance [7]	GM11								Per each formulation
a) Standard OIT (min. avg.) [9]	D3895	N.R.[9]	N.R.[9]	N.R.[9]	N.R.[9]	N.R.[9]	N.R.[9]	N.R.[9]	
--OR--									
b) High Pressure OIT (min. avg.) – % retained after 1,600 hours [10, 11]	D5885	50%	50%	50%	50%	50%	50%	50%	

1. Perform 10 readings. Eight (8) out of 10 readings must be greater than or equal to (≥) 7 mils, and the lowest individual reading must be ≥ 5 mils.
2. Alternate the measurement side for double-sided textured sheet.
3. Machine direction (MD) and cross-machine direction (XMD) average values should be on the basis of five (5) test specimens each direction.
   - Yield elongation is calculated using a gauge length of 1.3 inches.
   - Break elongation is calculated using a gauge length of 2.0 inches.
4. P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
5. Other methods, such as D4218 (muffle furnace) or microwave methods, are acceptable if an appropriate correlation to D1603 (tube furnace) can be established.
6. Carbon black dispersion (only near spherical agglomerates) for ten (10) different views: nine (9) in Categories 1 or 2 and one (1) in Category 3.
7. The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
8. It is also recommended to evaluate samples at 30 and 60 days to compare with the 90-day response.
9. Not recommended since the high temperature of the Standard OIT test produces an unrealistic result for some of the antioxidants in the UV-exposed samples.
10. The condition of the test should be 20-hour UV cycle at 75°C followed by 4-hour condensation at 60°C.
11. UV resistance is based on percent-retained value regardless of the original High Pressure OIT value.

Table 3 – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured HDPE Geomembranes

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]							
Shear strength,[2] lb/in.	57	80	100	120	160	200	240
Shear elongation at break,[3] %	50	50	50	50	50	50	50
Peel strength,[2] lb/in.	45	64	76	91	121	151	181
Peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
Shear strength,[2] lb/in.	57	80	100	120	160	200	240
Shear elongation at break,[3] %	50	50	50	50	50	50	50
Peel strength,[2] lb/in.	39	52	65	78	104	130	156
Peel separation, %	25	25	25	25	25	25	25

1. Also for hot air and ultrasonic seaming methods.
2. Value listed for shear and peel strengths are for four out of five test specimens; the fifth specimen can be as low as 80% of the listed values.
3. Elongation measurements should be omitted for field testing.

SECTION 6 – HORIZONTAL WETLAND TREATMENT TRAIN MATRIX MATERIAL AND VEGETATION

6.0 GENERAL

This section provides description and details of the Horizontal Wetland Treatment Train (HWTT) matrix materials and vegetation for the:

1. Surface Flow Wetland (SF Wetland)
    a. Filled with topsoil and planted with sedges.
2. Horizontal Subsurface Flow Wetland (HSSF Wetland)
    a. Filled with a mixed matrix and planted with cattails.
3. H-Series Aeration Channel (HSAC)
    a. Filled with rounded rock.
4. Rock Drain
    a. Filled with washed limestone.

6.1 SUBMITTALS

Submittals shall include the following.

	Supplier Information *	Approximate Quantity of Material	Material Extraction Source	Type of Material (i.e. Type of Wood Chip)	Laboratory Data Available	Material Specification	Material Gradation
SF Wetland							
Topsoil	X	X	X	X	X		
Sedges	X	X					
HSSF Wetland							
Rounded Rock	X	X	X	X	X		X
Wood Chips	X	X	X	X	X		X
Manure	X	X		X		X	
Sulfur Prill	X	X				X	
Fish Fertilizer	X	X				X	
Cattails	X	X					
H-Series Aeration Channel							
Rounded Rock	X	X	X	X	X		X
Rock Drain							
Limestone Rock	X	X	X	X	X		X

* Vendor name, contact name, address, telephone, and approximate quantity of material.

6.2 MATERIALS

6.2.1 SF Wetland

6.2.1.1 Topsoil

Topsoil may have to be amended to ensure nutrient concentrations are adequate to support wetland vegetation. Topsoil shall have the following characteristics:

1. Nitrogen content shall be in the range of 0.1% to 0.5% by volume to support the growth of emergent vegetation. If necessary, nitrogen should be supplemented to meet this technical specification.

2. Phosphorus content shall be in the range of 0.01% to 0.05% by volume to support the growth of emergent vegetation. If necessary, phosphorus should be supplemented to meet this technical specification.

3. Soil type can support the growth of wetland vegetation.

Any substitutions must be approved by the Engineer, in writing, prior to purchase.

6.2.1.2 Sedges

Sedges (*Carex sp.*) shall be purchased from a plant nursery. Sedges selected shall be approved by the Engineer, in writing, prior to purchase.

6.2.2 HSSF Wetland

6.2.2.1 Rounded Rock

Rounded rock shall be washed and 1.5-inch to 2-inch diameter. Rock shall pass 100% on a 2-inch screen and be retained on a 1.5-inch screen. Rock selected shall be free of fines and washed prior to use. Rock shall be purchased from Southwest Soils; price has been confirmed by the Engineer. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

6.2.2.2 Wood Chips

Wood chips shall be 1-inch to 2-inch diameter. Wood chips shall pass 100% on a 2-inch screen and be retained 100% on a 1-inch screen with minimal fines. Wood chips shall be purchased from Southwest Soils; price has been confirmed by the Engineer. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

6.2.2.3 Manure

Manure shall be sheep manure, premium amendment (60% manure and 40% composted aspen fines). Any substitutions must be approved by the Engineer, in writing, prior to purchase.

6.2.2.4 Sulfur Prill

Sulfur prill as available from Basin Co-op in Arriola, Colorado.

6.2.2.5 Fish Fertilizer

Alaska fish fertilizer as available from Durango Nursery, Home Depot, and Lowe's in Durango, Colorado.

6.2.2.6 Sulfate Reducing Bacteria

Sulfate-reducing bacteria (SRB) media in the pilot-scale subsurface flow wetland cell will be extracted and mixed with the mixed matrix material that makes up the wetland demonstration HSSF wetland. SRB media removed from the pilot-scale subsurface flow wetland cell shall be relatively free of fines. If significant fines are observed, SRB media must be approved by the Engineer, in writing, prior to use. If washing is required prior to placement, follow instructions provided by the Engineer.

6.2.2.7 Cattails

Cattails (*Typha sp.*) shall be purchased from a plant nursery. Cattails selected shall be approved by the Engineer, in writing, prior to purchase.

6.2.3 H-Series Aeration Channel

6.2.3.1 Rounded Rock

Rounded rock shall be washed and 3-inch to 6-inch diameter. Rock selected shall be free of fines and washed prior to use. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

6.2.4 Rock Drain

6.2.4.1 Limestone Rock

Limestone rock shall be 1.5-inch diameter crushed and washed limestone. Rock shall pass 100% on a 2-inch screen and be retained 100% on a 1.5-inch screen. Rock selected shall be free of fines and washed prior to use. Limestone shall be purchased from C&E Concrete; price has been confirmed by the Engineer. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

6.2.4.2 Manganese Oxidizing Bacteria

Rock media in the pilot-scale wetland rock drain cell, covered in manganese-oxidizing bacteria, will be extracted and mixed with the limestone rock that makes up the wetland demonstration Rock Drain. Consult with the Owner's Representative or Engineer during the removal of the rock. The Engineer shall determine if rock needs to be washed of fines (i.e., sediment or iron deposits) prior to placement in the Rock Drain. Contractor shall provide a cost to clean rock based upon any instruction provided. Suitable wash water shall be as specified elsewhere in these technical specifications. Disposal of wash water shall be coordinated with the Owner's Representative or Engineer.

6.3 EXECUTION

6.3.1 SF Wetland

6.3.1.1 Topsoil

Topsoil shall be placed in the SF Wetland. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The topsoil shall be spread evenly and graded in accordance with the Construction Drawings. The topsoil shall not be compacted by spreading equipment or machinery.

6.3.1.2 Sedges

Sedges shall be transported and planted with care to ensure the plant roots and surrounding topsoil are intact during planting. The Sedges shall be planted with approximately 2-foot on center spacing. Contractor shall confer with the Engineer on hole size and depth for planting.

6.3.1.3 Rounded Rock

Rounded rock shall be placed in the inlet and outlet of the SF Wetland. Loading and unloading of the rounded rock shall be performed to minimize gradation of the material. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The rounded rock shall be spread evenly and graded in accordance with the Construction Drawings. The rounded rock shall not be compacted by spreading equipment or machinery.

6.3.2 HSSF Wetland

6.3.2.1 Mixed Matrix

1. The mixed matrix shall be mixed off-site if a suitable mixing site can be located. Contractor shall confirm such a location with the Owner's Representative. Otherwise, the mixed matrix shall be mixed on-site. At the mixing site, the material shall be mixed in maximum volumes of one truckload. The unloading and mixing process must be observed by the Engineer. When the matrix is adequately mixed, it shall be loaded into a transport truck for hauling. From the mix pile, a minimum 1-foot depth shall be left in place to ensure that no ground materials are scraped into the matrix mix. Loading and unloading shall be performed to minimize gradation of the material.

2. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The mixed matrix shall be spread evenly and graded in accordance with the Construction Drawings. The mixed matrix shall not be compacted by spreading equipment or machinery.

3. Mixture of materials shall be as presented in the table below:

Material	% by Volume
1.5-inch Washed, Rounded Rock	60%
1 to 2-inch Wood Chips	35%
Manure	4.6%
Sulfur Prill	0.38%
Liquid Fish Fertilizer	0.02%

4. SRB media from the pilot-scale subsurface flow wetland cell will be extracted and uniformly mixed into the mix matrix material. A SRB inoculation ratio of 1:100 by volume will be used, unless otherwise directed by the Engineer.

6.3.2.2 Rounded Rock

Rounded rock shall be placed in the inlet and outlet of the HSSF Wetland. Loading and unloading of the rounded rock shall be performed to minimize gradation of the material. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The rounded rock shall be spread evenly and graded in accordance with the Construction Drawings. The rounded rock shall not be compacted by spreading equipment or machinery.

6.3.2.3 Cattails

Cattails shall be transported and planted with care to ensure the plant tubers remain intact. The Cattails shall be planted with approximately 2-foot on center spacing. Contractor shall confer with the Engineer on hole size and depth for planting

6.3.3 H-Series Aeration Channel

6.3.3.1 Rounded Rock

Rounded rock shall be placed in the entire aeration channel. Loading and unloading of the rounded rock shall be performed to minimize gradation of the material. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The rounded rock shall be spread evenly and graded in accordance with the Construction Drawings. The rounded rock shall not be compacted by spreading equipment or machinery.

6.3.4 Rock Drain

6.3.4.1 Limestone Rock

Washed limestone shall be placed in the Rock Drain. Loading and unloading of the limestone shall be performed to minimize gradation of the material. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The limestone shall be spread evenly and graded in accordance with the Construction Drawings. The limestone shall not be compacted by spreading equipment or machinery.

6.3.4.2 Rounded Rock

Rounded rock shall be placed in the inlet and outlet of the Rock Drain. Loading and unloading of the rounded rock shall be performed to minimize gradation of the material. Placement equipment must not impact the geomembrane. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The rounded rock shall be spread evenly and graded in accordance with the Construction Drawings. The rounded rock shall not be compacted by spreading equipment or machinery.

6.3.4.3 Manganese Oxidizing Bacteria

Manganese-oxidizing bacteria from the pilot-scale wetland rock drain cell will be extracted and uniformly mixed with the 1.5-inch diameter limestone rock prior to placement. All rock extracted from the pilot-scale wetland rock drain cell will be mixed with the limestone rock to promote in establishment of manganese-oxidizing bacteria in the wetland demonstration Rock Drain.

SECTION 7 – VERTICAL WETLAND TREATMENT TRAIN MATRIX MATERIAL

7.0 GENERAL

This section provides description and details of the Vertical Wetland Treatment Train (VWTT) matrix materials for the:

1. Vertical Flow Biotreatment Cell (VFBC)
    a. Filled with organic substrate and 1.5-inch washed angular limestone.
2. V-Series Aeration Cascade (VSAC)
    a. Filled with 3-inch washed angular limestone.

7.1 SUBMITTALS

Submittals shall include the following:

	Supplier Information *	Approximate Quantity of Material	Material Extraction Source	Type of Material (i.e. Type of Wood Chip)	Laboratory Data Available	Material Specification	Material Gradation
Vertical Flow Biotreatment Cell							
Wood Chips	X	X	X	X	X		X
Wood Shavings	X	X	X	X	X		X
Manure	X	X		X		X	
Hay	X	X		X		X	
1.5-inch Washed Limestone	X	X	X	X	X		X
V-Series Aeration Cascade							
3-inch Washed Limestone	X	X	X	X	X		X

* Vendor name, contact name, address, telephone, and approximate quantity of material. Where possible, vendors providing materials for the HWTT will be used.

7.2 MATERIALS

7.2.1 Vertical Flow Biotreatment Cell

7.2.1.1 Wood Chips

Wood chips shall be greater than 1-inch nominal diameter. Wood chips shall be retained 100% on a 1-inch screen with minimal fines. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

7.2.1.2 Wood Shavings

Wood shavings shall be 0.5-inch nominal diameter. Wood shavings shall be retained 100% on a 0.5-inch screen with minimal fines. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

7.2.1.3 Manure

Composted steer manure. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

7.2.1.4 Hay

Chopped alfalfa hay. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

7.2.1.5 Sulfate Reducing Bacteria

For the VWTT, SRB media from the column test will be transported to the site and mixed with the mixed matrix material that makes up the VWTT anaerobic biotreatment cell.

7.2.1.6 Limestone Rock

Limestone rock shall be 1.5-inch nominal diameter washed angular limestone. Rock shall pass 100% on a 2-inch screen and be retained 100% on a 1-inch screen. Rock selected shall be free of fines and washed prior to use. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

7.2.2 V-Series Aeration Cascade

7.2.2.1 Limestone Rock

Limestone rock shall be 3-inch nominal diameter washed angular limestone. Rock shall pass 100% on a 4-inch screen and be retained 100% on a 2-inch screen. Rock selected shall be free of fines and washed prior to use. Any substitutions must be approved by the Engineer, in writing, prior to purchase.

7.3 EXECUTION

7.3.1 Vertical Flow Anaerobic Biotreatment Cell Mixed Matrix

1. The mixed matrix may be mixed off-site if a suitable mixing site can be located. Contractor shall confirm with the Engineer. Otherwise, the mixed matrix shall be mixed on-site. At the mixing site, the material shall be mixed in maximum volumes of 36 cubic yards (10% of the total matrix volume of approximately 360 cubic yards). The unloading and mixing process must be observed by the Engineer. When the matrix is adequately mixed, it shall be loaded in the transport truck for hauling. Contractor shall ensure that

no ground materials are scraped into the matrix mix. Loading and unloading shall be performed to minimize gradation of the material.

2. Placement equipment must not impact the geomembrane or influent/effluent piping networks. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The mixed matrix shall be spread evenly and graded in accordance with the Construction Drawings. The mixed matrix shall not be compacted by spreading equipment or machinery.

3. Mixture of materials shall be as presented in the table below:

Material	% by Volume
>1-inch Wood Chips	65%
0.5-inch Wood Shavings	25%
Manure	5%
Hay	5%

4. SRB media from the column test anaerobic cell will be extracted and mixed into the matrix materials.

7.3.2 Washed Limestone

Washed limestone shall be placed in the VWTT anaerobic biotreatment cell and aeration cascade (1.5-inch and 3-inch limestone, respectively). The 1.5-inch washed angular limestone shall comprise the drainage layer in the biotreatment cell (to be placed over and around the outlet piping array). The 3-inch washed angular limestone shall be placed in the downstream half of each HDPE trough of the aeration cascade.

The loading and unloading of the limestone shall be performed to minimize gradation of the material. Placement equipment must not impact geomembranes, piping, or the integrity of the aeration cascade troughs. Use of equipment on the geomembrane is permissible only in accordance with the manufacturer's recommendations. The limestone shall be spread evenly and graded in accordance with the Construction Drawings. The limestone shall not be compacted by spreading equipment or machinery.

7.3.3 Clean Cover Over Calcine Deposits

In areas disturbed during the construction of the VWTT, if calcines are present at the final grade elevation outside of lined areas, the calcines shall be covered to a minimum depth of 6 inches with suitable backfill. Refer to Section 3 – Earthwork.